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### Automated Impact Device

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# Automated Impact Device

BY

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With Instruction By Dr. Allen Jackson

A thesis submitted in partial fulfillment of the requirements for the departmental  
honor's degree of

Mechanical Engineering

at the

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## **Nomenclature:**

AID- Automated Impact device

PLC- Programmable Logic Controller

Basic- Beginner's All-purpose Symbolic Instruction Code

HPM- Hits per minute

V- Voltage

VAC- Voltage Alternating Current

POIS- Phototransistor Optical Interrupter Switch

$F_I$  – Impact Force

S - Slow Down Distance (m, ft)

## **I. Abstract**

This report outlines the progress and development of an automated impact device (AID). This device was designed to be inexpensive, user-friendly, and modular. Developed with the parameters of vibration analysis, the AID can perform a variety of experimental procedures. Using simple C code and components that are both affordable and easy to obtain, the AID was designed to perform the same task as its more expensive counterparts. With this thought-process, the device was engineered to easily and quickly interchange components depending on the required task. Outlined in the report is the code used to operate the AID and the basic components used to create the circuitry. Restrained by time and budget, only a functional prototype showing the variable frequency and force of the impacts was created. Included in the

experimental section is the limited testing performed with the AID. This data shows the validity of the design, needing further refinement to be a proper lab testing device.

## II. Introduction

No other aspect of society has been impacted by technology more than scientific research. Many experimental tasks and techniques that have been performed manually in the past are now automated. Manual processes add more random uncertainty to an experiment. Implementation of technology has been able to further minimize epistemic uncertainty caused by human handling and increase test consistency. Vibration testing is no different. Using the AID to strike a material, an impulse response is created. The impulse excitation causes vibrations inside of the test material that can be collected and analyzed. Natural frequencies, modal masses, modal damping ratios, and modal shapes can be calculated from the data collected. The vibration testing requires an operator to use a specialized impact hammer to strike an object. As the experiments have become more sophisticated, it makes sense for scientific research to turn towards technological automation. The downside to relying on more technology is the cost involved. This not only includes the cost of the hardware, but also training the user how to operate the device effectively. The goal of this project is to create a device that is both user friendly and cost effective, directing attention towards the Arduino.

Why Arduino? Directly quoted from the official Arduino website, “The Arduino is an open-source electronics platform based on easy-to use hardware and software”.<sup>1</sup> In simple terms, the Arduino allows someone with limited experience of coding and electronics to create a complex electronic system. The open-source software of the Arduino makes finding code examples online

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<sup>1</sup> <https://www.arduino.cc/en/Guide/Introduction>

simple and free. Besides being easy to work with, the Arduino is inexpensive to buy; this includes the sensors and other hardware that would be used in conjunction with the device. The total cost is less than sixty dollars. In addition to the reasons stated above, the Arduino also accepts both analog and discrete inputs. This allows the use of a potentiometer to supply a varying input voltage. The Arduino software will run on Windows, Macintosh OS, and Linux in contrast to most micro-controllers only working with Windows.<sup>2</sup> Included in the appendix is the specification sheet on the Arduino. It is designed to be a stand-alone device that can be programmed, then perform tasks based on its programming. In the case of the AID, it performed the job which a large relay board would have been responsible.

In addition, it allows the user to modify different parameters of the code to change the perform of the device instead of having to change out components of a circuit. This speaks volumes to the flexibility of the platform. The goal of the project is to create a device modular, user-friendly, and practical. The Arduino ranks high in all three categories. In conjunction with the Arduino, a simple relay circuit is used to shield the 5V system. By using a relay to shield the 5V system, the Arduino can be used to control a solenoid of any voltage. As a shielded system, the device became even more modular. This allows different solenoids operating at different voltages and currents to be controlled by the same main circuit. By creating a modular system, different forces can be achieved depending on the requirement of the experiment. Combining all of these design constraints, the AID was fabricated.

### **III. Experimental Apparatus**

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<sup>2</sup> <https://www.arduino.cc/en/Guide/Introduction>

The automated impact device is designed to interpret an analog voltage input and convert it into a time delay to fire a solenoid at measurable intervals. By making a simple circuit consisting of a voltage source and potentiometer, a varied voltage can be measured by the analog input pin of the Arduino. This simple circuit, and the few parts below are the major components needed to create the apparatus. Included in this list is the: Arduino, LCD screen, relay, and breadboard. Shown below in Figures 3.1-3.4 are these main components. Others parts have auxiliary functions, but will not be directly mentioned in this portion of the report; for a full list refer to the *Bill of Materials*.

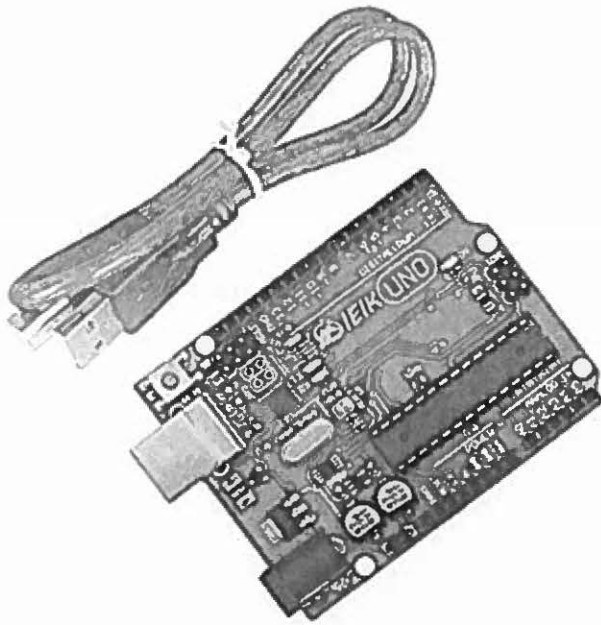


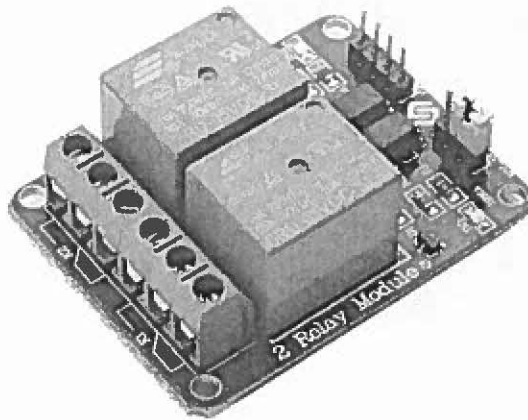
Figure 3.1 Arduino Board



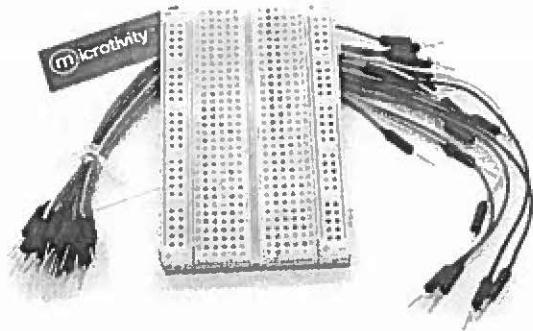
Figure 3.2 LCD Screen (Arduino Compatible)

<sup>3</sup> [https://www.amazon.com/gp/product/B00P2FX9WY/ref=oh\\_aui\\_detailpage\\_o02\\_s02?ie=UTF8&psc=1](https://www.amazon.com/gp/product/B00P2FX9WY/ref=oh_aui_detailpage_o02_s02?ie=UTF8&psc=1)

<sup>4</sup> [https://www.amazon.com/gp/product/B019D9TYMI/ref=oh\\_aui\\_detailpage\\_o04\\_s00?ie=UTF8&psc=1](https://www.amazon.com/gp/product/B019D9TYMI/ref=oh_aui_detailpage_o04_s00?ie=UTF8&psc=1)



5



6

Figure 3.3 5-volt relay capable of handling 220 VAC

Figure 3.4 Breadboard with connectors

As stated in the introduction, the idea of the project is to create a balance between functionality and simplicity. It would have been possible to use a P.L.C, but it would have also added unnecessary complexity. Using a few beginner Arduino websites<sup>7</sup>, the basic wiring was completed in a couple hours. Nestling all the components in the box of the first prototype was quite a challenge. It was important to position each component to prevent cross wiring (Figure 3.5).

<sup>5</sup> [https://www.amazon.com/gp/product/B00E0NTPP4/ref=oh\\_aui\\_detailpage\\_o02\\_s02?ie=UTF8&psc=1](https://www.amazon.com/gp/product/B00E0NTPP4/ref=oh_aui_detailpage_o02_s02?ie=UTF8&psc=1)

<sup>6</sup> [https://www.amazon.com/gp/product/B004RXKWDQ/ref=oh\\_aui\\_detailpage\\_o04\\_s01?ie=UTF8&psc=1](https://www.amazon.com/gp/product/B004RXKWDQ/ref=oh_aui_detailpage_o04_s01?ie=UTF8&psc=1)

<sup>7</sup> <https://www.arduino.cc/en/Tutorial/LiquidCrystalDisplay>



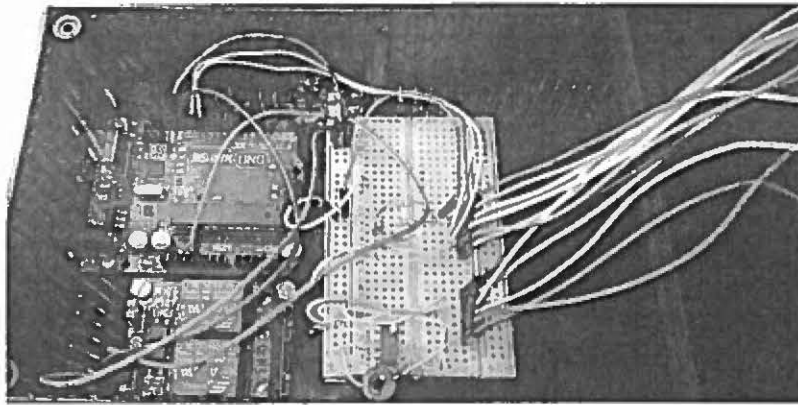


Figure 3.5 Components in place and wired

There was also the fear of totally enclosing the electronic components without a cooling system. After leaving it function for over an hour at the highest setting, the cover was removed to look for signs of overheating. Everything was cool to the touch; the only part that became warm was the solenoid, which is not able to damage any other components. After finishing the physical wiring, the next step was to develop the code to control the device.

## IV. Arduino Code

After completion of the hardware, it was necessary to begin the process of learning code. This code was developed by a beginner, for beginners. Making the code as simplistic as possible and labeling what each line was responsible for, made a code that a person with a background as limited to Basic<sup>8</sup> could understand. Below in Figure 4.1, is the first section of the code used to operate the AID.

<sup>8</sup> <http://whatis.techtarget.com/definition/BASIC-Beginners-All-purpose-Symbolic-Instruction-Code>

```

/*
The circuit:
* LCD RS pin to digital pin 7
* LCD Enable pin to digital pin 8
* LCD D4 pin to digital pin 9
* LCD D5 pin to digital pin 10
* LCD D6 pin to digital pin 11
* LCD D7 pin to digital pin 12
* LCD R/W pin to ground
* LCD VSS pin to ground
* LCD VCC pin to 5V
*/

#include <LiquidCrystal.h>

#define ACTIVATION_TIME 100
//In milliseconds
#define SCALE_FACTOR 5

int relayPin = 13;
int potPin = A0;
int delayTime = 1000;
LiquidCrystal lcd(7, 8, 9, 10, 11, 12);

```

Figure 4.1 Section 1 of 3 for the AID Apparatus

The first ten lines of code, are automatically displayed on every code developed using the Arduino software. It is a basic guide to what each pin does and is helpful for troubleshooting.

The function `#include` allows a programmer to include libraries from an alternate source to perform a function in the sketch<sup>9</sup>. To assign a constant value, `#define` is used to assign a name to the value before the sketch (Arduino code) is compiled<sup>10</sup>. The “int” function stores integer values for the sketch. These values range from -32,768 to 32,767<sup>11</sup>. This becomes important later in the code because one of the values is larger than the upper limit.

<sup>9</sup> <https://www.arduino.cc/en/Reference/Include>

<sup>10</sup> <https://www.arduino.cc/en/reference/define>

<sup>11</sup> <https://www.arduino.cc/en/reference/int>

```

void setup() {
  // put your setup code here, to run once:
  pinMode(8, OUTPUT);
  pinMode(A0, INPUT);
  // baud rate Bits of information per second
  Serial.begin(9600);
  lcd.begin(16, 2);
  lcd.print("Strikes Per Min:");
}

```

Figure 4.2 Section 2 of 3 for the AID

This section of code in Figure 4.2 is only processed one time during the initial operation of the sketch. In this portion, parameters that will not change during the apparatus's operation are defined. The pins, tasks, and the baud rate for the LCD are outlined. A baud rate of 9600 is a standard value and worked well in this application.

Displayed in figure 4.3 is the final section of code.

```

void loop() {
  // put your main code here, to run repeatedly:
  int Time_Variable = analogRead(A0);
  // Below code creates the time divisions (old code)
  //delayTime = 128000/Time_Variable;
  int HPM = Time_Variable / 17;
  if(HPM < 10)
    HPM = 10;
  // Needed 32 bit instead of 16
  delay((60000L / HPM) - ACTIVATION_TIME);
  // Below code allows Shift control M to read the serial display
  Serial.println(HPM);
  // LCD related code
  // Line placement
  lcd.setCursor(0, 2);
  //What is displayed
  lcd.print(HPM);
  //Tells the arduino how long to delay itself

  //Tells which pin to write
  digitalWrite(relayPin, LOW);
  // How long to delay the arduino
  delay(ACTIVATION_TIME);
  // Tells which pin to write
  digitalWrite(relayPin, HIGH);
}

```

Figure 4.3 Section 3 of 3 for the AID Apparatus

Section three of the code is constantly refreshed as the device operates. This allows for changes in the environment to be perceived and converted into usable outputs. The `analogRead` is the input pin attached to the potentiometer. As the resistance is changed the input voltage changes. The value ranges from 0 to 1024. To get time divisions of approximately one hit per second, this value is divided by 17. That gives the HPM. Immediately below this line is the “if” statement which places a minimum value on the system. Commented out is the old code, which does work, but is less efficient with the Arduino. Even though it is not in use, it can function as troubleshooting device. The next line of code is the most important line of the sketch. The `delay` function pauses the program for specified time (in milliseconds)<sup>12</sup>. This is not the most elegant or efficient way to create interval delays in the system, but is by far the simplest and most user friendly. Inside the parentheses, the “60000L” is an interesting portion of code to point out. Without the “L” the Arduino software would register an error. As mentioned about the “int” value, it can only store values between -32,768 to 32,767. To allow the software to be able to compute the larger value, it was necessary to create a long integer. The next three lines are used to print the HPM value on the second line of the LCD screen. The two “`digitalwrite`” lines tell the software where to send the data it has collected after each cycle. The final portion of the code delays the Arduino’s operation to allow the solenoid to fire before refreshing the sketch. Laying the code out in a simplistic way as possible and properly explaining/labeling each line’s function, creates a code that can be easily manipulated by someone unfamiliar with coding.

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<sup>12</sup> <https://www.arduino.cc/en/Reference/Delay>

## V. Experimental Results

Due to time restraints, it was necessary to create a simulated impact test. This was done by using a wind chime and a small solenoid. Designing a frame to suspend a wind chime for the solenoid to strike, allowed for an audible response when struck. It demonstrates the harmonic properties caused by the impact, as it would in an actual test material. The prototype frame is shown below in Figure 5.1 before it was painted.

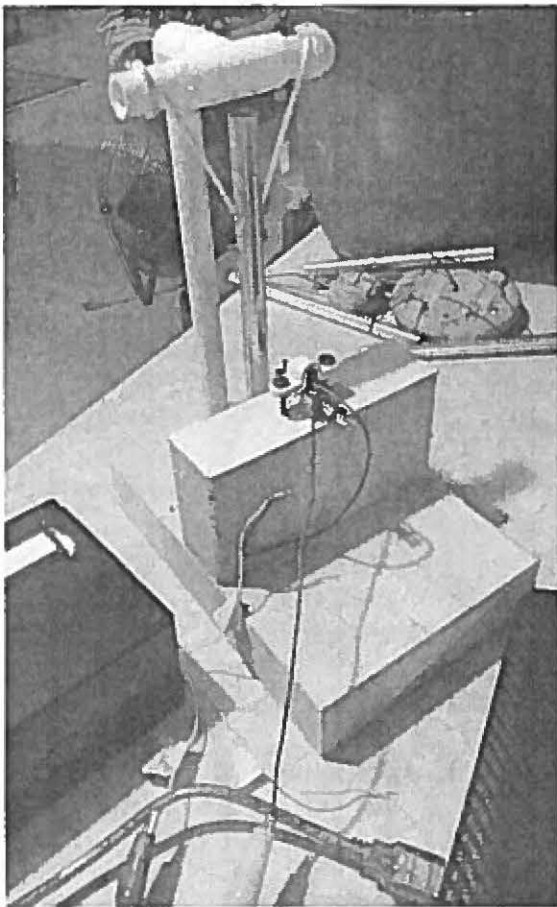


Figure 5.1 Automated Impact Device test frame

The next step of the project was to develop a method to measure the impact force of the solenoid. The manufacturer provided a force of 600g at 12V for the solenoid.<sup>13</sup> This value provided a baseline to evaluate any experimental data collected or calculated. Conveniently, magnetic force has a linear relationship. In Equation 5.1 is the relationship of electromagnetic field force.

Equation 5.1 magnetic force

$$B = \mu \frac{NV}{LR}^{14}$$

The portion N/L is a representation of the density of the coils, where V/R is the current in the system. The Greek letter  $\mu$  is the permeability of the core.<sup>15</sup> The only value changing in the equation will be voltage. Using this relationship, other force values can be found at different voltages. The solenoid used has a functional range from 5V-12V. Show below in Table 5.1 is the theoretical force calculations for the different voltages using this relationship.

Solenoid Force Values	
Voltage	Force
12 volts	59 Newtons
11 volts	54 Newtons
10 volts	49 Newtons
9 volts	44 Newtons
8 volts	39 Newtons
7 volts	34 Newtons
6 volts	29 Newtons
5 volts	23 Newtons

Table 5.1 Theoretical Force Calculations

<sup>13</sup> [https://www.amazon.com/Uxcell-Frame-Solenoid-Electromagnet-Stroke/dp/B00HR8H38A/ref=sr\\_1\\_2?s=industrial&ie=UTF8&qid=1489349518&sr=1-2&keywords=solenoid](https://www.amazon.com/Uxcell-Frame-Solenoid-Electromagnet-Stroke/dp/B00HR8H38A/ref=sr_1_2?s=industrial&ie=UTF8&qid=1489349518&sr=1-2&keywords=solenoid)

<sup>14</sup> Schimpf, Paul H. "A Detailed Explanation of Solenoid Force." Web.

<sup>15</sup> Schimpf, Paul H. "A Detailed Explanation of Solenoid Force." Web.

Measuring the velocity proved to be much more difficult. It could have been its own individual project because of its complexity. The ability to measure the velocity without interfering with the functionality turned out to be challenging without expensive instrumentation. Rough estimates could be made, but without a baseline of an actual velocity it would be impossible to use them with any confidence. Using another Arduino and guidance from Dave Kender, a rudimentary measurement system was devised. Using a phototransistor optical interrupter switch (POIS for short) the average velocity of the stroke could be measured. The technical specifications for the POIS can be found in the appendix. Using a piece of thin metal with a slot cut out for the POIS to use as an index point, the Arduino displayed the time interval in which the solenoid traveled. Shown in Figure 5.2 is the configuration of the speed test without any of the wiring and a cardboard mock-up of the metal piece. Figure 5.3 is with the wiring hooked up sending information to the Arduino.

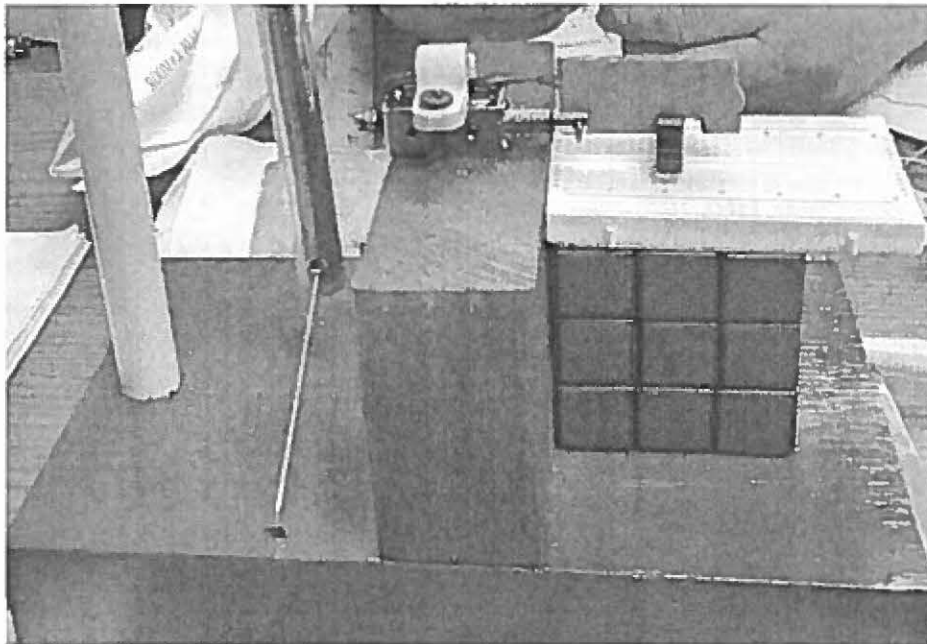


Figure 5.2 Velocity Test Mock-Up

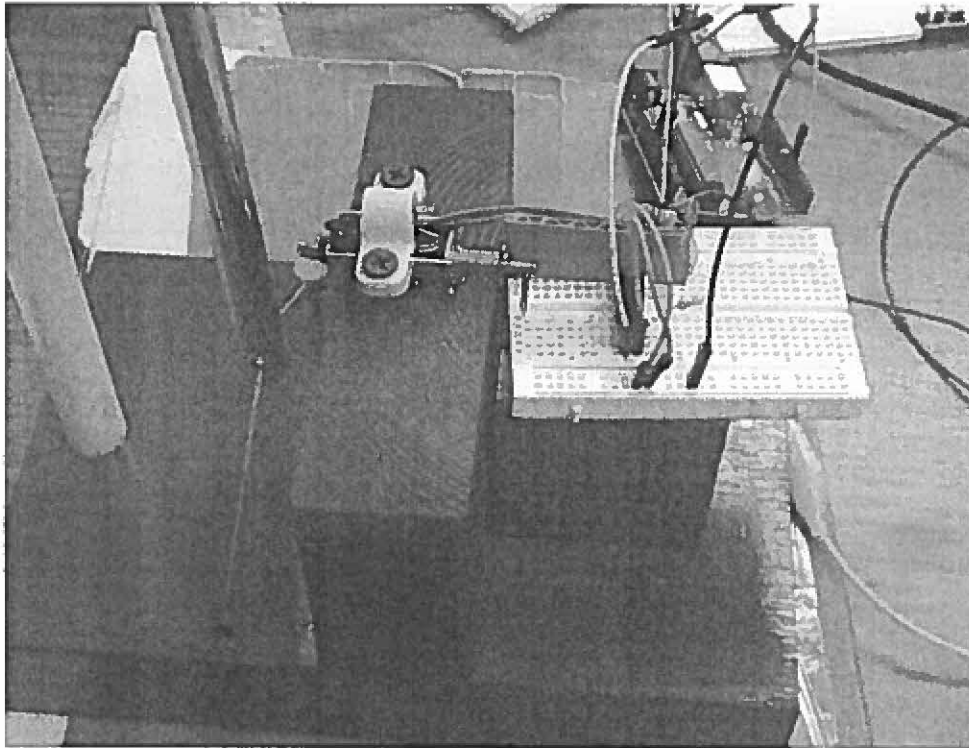


Figure 5.3 Velocity Test Procedure

The POIS consists of a gallium arsenide infrared emitting diode coupled with a silicon phototransistor in a plastic housing.<sup>16</sup> Shown in Figure 5.4 is the shape of the POIS. Between the two “ears” of the component is where the piece of metal travels. When the small gap in the metal travels between the “ears” the output switches from off to on. With a known width of the gap in the metal, the velocity can be calculated using the equation below.

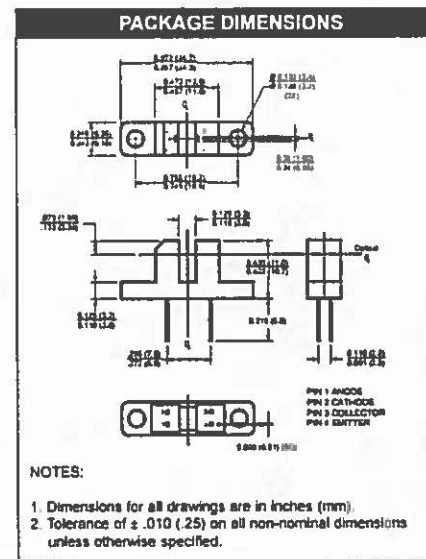
$$Velocity = \frac{X}{T}$$

<sup>16</sup> <http://www.jameco.com/Jameco/Products/ProdDS/320901FSC.pdf>



The velocities for different voltages are shown below in Table 5.2. Using Excel, other velocities at different voltages can be predicted. This allows the experimenter to know what voltage range they will need to operate the solenoid to generate the desired velocity. With more refinement, the system could be fitted with an integrated POIS to monitor the velocity of each individual strike.

Figure 5.4 POIS Shape and Design



Once the device was set up the auxiliary Arduino could monitor the time which the POIS switched from off to on. Shown in Figure 5.5 is an example of the numbers that would be seen by the user.

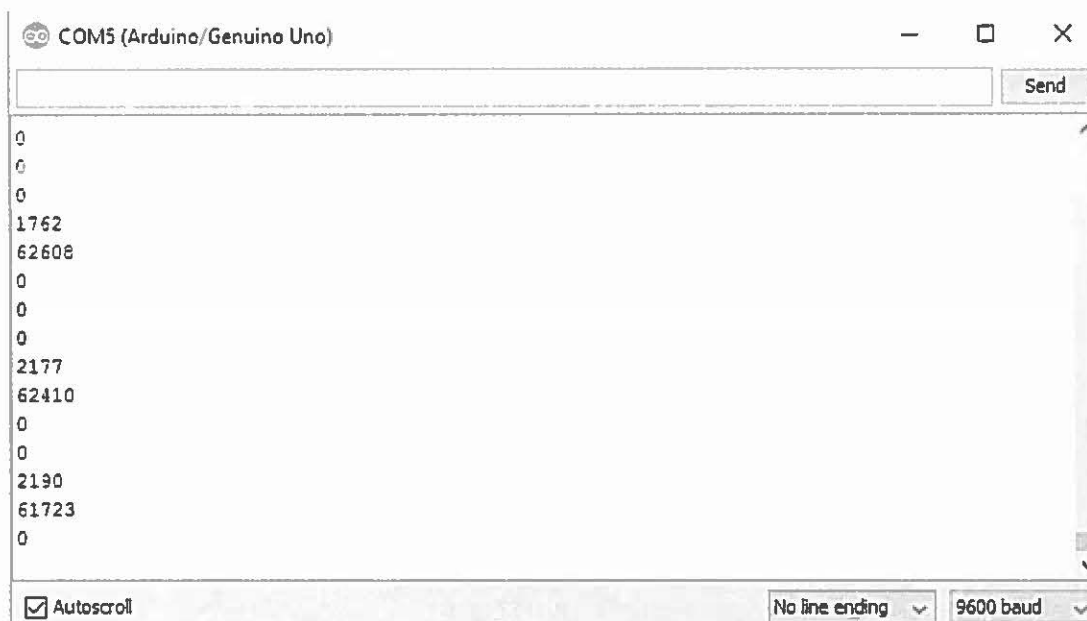


Figure 5.5 Arduino Readout screen of velocity

The first non-zero number is the strike time (smaller value), followed by the return time (larger value). The shaft return is powered by an external return spring, not the magnetic force. These time values are measured in micro-seconds ( $10^{-6}$ ). The size of the slot is 4mm. Using the simple formula above, a rough velocity could be tabulated. For this part, Excel was used to calculate average velocities for 4 different voltages, but with more time a script could be written in the Arduino software to automatically convert the values into velocity. This could then be displayed with the HPM found on the readout LCD screen.

Along with the other work that could be done, an integrated monitor system could be installed. Ordering a POIS with ears wide enough for the plunger to pass through and cutting a small notch in the shaft to allow the POIS to index off of would create a seamless and effective means to calculate velocity. This can also serve as a roundabout way to measure the force of the impact if the mass of the striker is changed or if a different voltage is applied. The solenoid used for this experiment has a functional range of 5V-12V according to the manufacturer. It is optimized to operate at 12V. This became clear because the data is most consistent for the 12V sample. Below in Figure 5.6 is a chart of the voltages and their corresponding velocities. The numerical values are displayed in Table. The x-axis is the number of the test and the y-axis is the velocity in (m/s). At 6 volts the velocity was inconsistent. This is because the voltage is approaching the minimum operating voltage of the solenoid. As the voltage was increased to the optimal value, the time intervals became more consistent. The goal was to be able to vary the force of the solenoid by adjusting the voltage. Based on the results of this experiment, this is a viable concept, as long as the voltage is kept close to the manufacturer's voltage recommendations and the velocity is monitored.

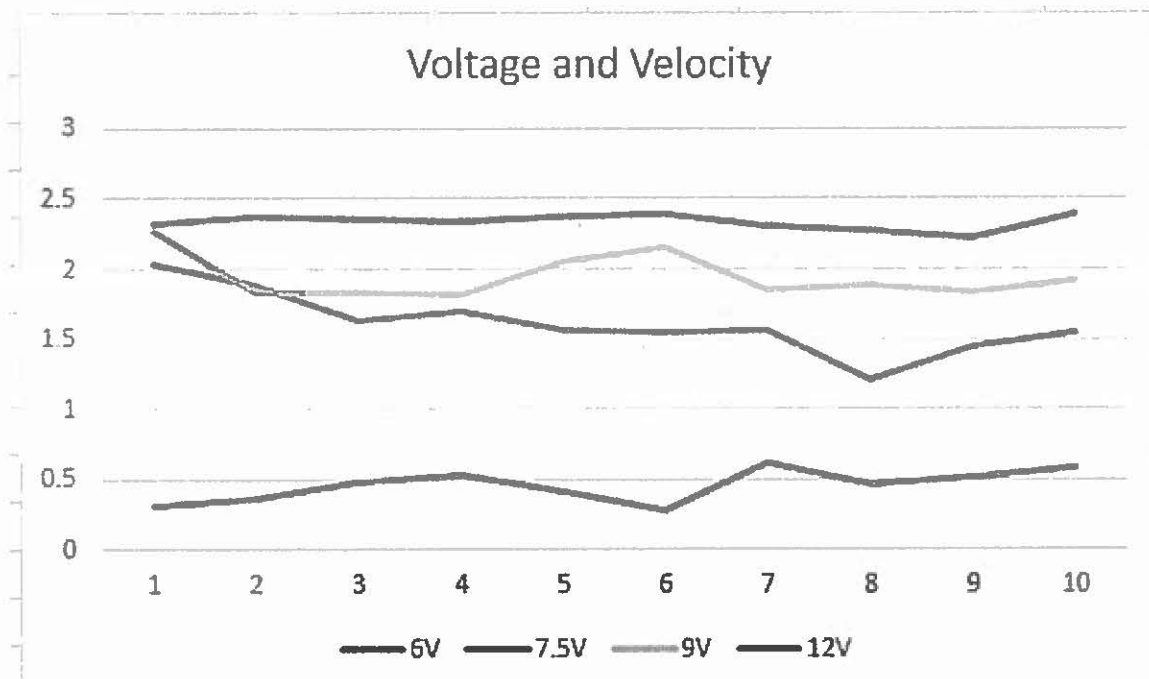


Figure 5.6 Velocity of the Impact rod with different voltages

Velocity (m/s)	6V	7.5V	9V	12V
1	0.306701	2.040816	2.270148	2.325581
2	0.360913	1.878816	1.837391	2.364066
3	0.474383	1.634655	1.826484	2.352941
4	0.531208	1.697073	1.815706	2.34055
5	0.406918	1.557632	2.058672	2.368265
6	0.27931	1.536688	2.145923	2.389486
7	0.617093	1.56189	1.855288	2.304147
8	0.450248	1.208094	1.875293	2.275313
9	0.501065	1.436266	1.826484	2.217295
10	0.57282	1.539646	1.914792	2.38379
Sum	4.50	16.09	19.43	23.32
Average	0.45	1.61	1.94	2.33 (m/s)

Table 5.2 Velocity vs Voltage

The velocity of the impact rod is directly proportional to the voltage. Using this information, an experimenter can predict the needed solenoid and voltage to create a desired impact velocity. These values are not accurate enough to use for modal calculations, but provide a sanity check when comparing experimental values with theoretical values.

Given more time, precise values could be obtained. The Arduino proved to be accurate and repeatable during the testing. The code was also easily modified during testing, with a down time of less than 5 minutes. In practical applications, this would allow the operator to adapt to different situations in the lab.

## **VI. Future work**

The project proved to be more intricate than at first approach. The devil was truly in the details. It seemed fixing one problem would cause a new one to appear. In its current state, it fulfills the requirements of the project parameters, but someone with a more in-depth background in coding and vibration testing to refine the AID. First, a more efficient code could be used to delay the impact of the solenoid. The largest disadvantage of the script is the Arduino does not process any data during the duration of the time delay, thus making it inoperable to do any other task than delay the solenoid. This is problematic if a user wants to use the Arduino to monitor the system or perform a completely different task related to the project. Also with more work it would be possible to add monitoring sensors. The incorporation of a permanent POIS would be an excellent way to monitor the constancy of the strike velocity. In addition to this setup, a load cell could be permanently installed on the impact head to measure the force of each individual strike. All that is left to prepare the device for lab testing is to install the specialized impact head. The use of the device in an actual lab setting was never achieved because of the lack of time and knowledge. Without taking ME 4600 Mechanical Vibrations, it was difficult to fully grasp the

concept of modal analysis. The end-goal was to create a chart/user manual, making force calculations easy with the several types of heads, solenoids, and voltages. The prototype stage of the project is completed; further testing, data collection, data analysis, and adaptations are required to refine the product into a finished lab device.

## VII. Conclusion

This project was both challenging and rewarding. It required complex thinking and problem-solving that is often overlooked in the classroom environment. One of the more thought-provoking aspects of the project was starting from nothing but a concept, and turning it into a fully-functioning device. Much like driving in a maze without directions, idea after idea led only to dead-ends. With the help of Dr. Jackson and others, ideas were pursued one at a time until a viable option was realized. With the goal of simplicity in mind, it was difficult to find a system electronically controlled, that could deliver sharp impulses over a short amount of time. An actuator was too slow, and a hydraulic/pneumatic system was too complex/expensive to integrate into the project. The solenoid is far from perfect for the application, but it was the best choice out of the other options, giving the user an easy to operate device. With a relay shielded circuit, it is possible to use higher voltage rated solenoids to deliver various levels of force. Having multiple solenoids on hand which can easily be swapped out, allows the user to adapt to the needs of the experiment. After deciding on a force delivery system, a control module had to be created. At first, a mechanical circuit using varying capacitance seemed like a good option, but with the need to run different voltages through the system the idea soon ran into problems. It limited the range of the voltage/ampereage that would operate the solenoid properly. With limited experience in the past with an Arduino, it seemed like a viable candidate to investigate. It also had its own set of limitations. Operating on 5V, it was necessary to figure out how to shield the Arduino, especially

for voltages as large as 220 VAC. The hardest part was developing a functional code that was easy to operate. The thesis turned from mechanical engineering to computer science at this point. It showed how resourceful an engineer must be when faced with a problem. Often the solution requires knowledge from multiple disciplines of engineering to reach a solution. Armed with advice from friends and advisors, the coding process began. After 8 versions of the code, a useable sketch was finalized. It is not the most efficient or elegant code, but it performs the task.

More importantly than creating a lab-ready AID was the knowledge gained while building and researching the project. When a reporter asked Thomas Edison about developing the lightbulb, "How did it feel to fail 1,000 times?" Edison replied, "I didn't fail 1,000 times. The light bulb was an invention with 1,000 steps." The statement above is a one sentence summary of the entire process of creating the automated impact device. Even with all the hurdles encountered, a usable prototype was developed.

## **VIII. Acknowledgments**

During this independent study, many various aspects of engineering were required. Research to complete the project involved many different disciplines of engineering including electrical, mechanical, and computer science. The entire project was a humbling event. The scope of the project was severely cut down as it was clear time was not going to allow for it to be completed in a professional manner. The biggest lesson of this project was not the technical skills developed, but the interpersonal skills of asking for help and learning how to articulate a question to get a proper answer. For this thesis, a wealth of knowledge was gained from others. First off, Dr. Jackson provided guidance and direction on how to formulate the bounds of the project. He knew when parts needed to be eliminated to make the project feasible. Dr. Jackson's experience as a researcher in the past was a priceless addition to this thesis.

David Kender provided help with coding the Arduino. He provided his class notes, looked at the code, and showed the proper process of debugging. The other resource used to help with the code was Austin Ferguson, who is currently in school for Computer Engineering. He provided insight on where to look for coding resources. He also had experience doing small component wiring which proved to be extremely handy. These people allowed the project to go much smoother than trying to research each answer on the internet and in books. Without them the project would still be a box with a bunch of wires, instead of a functioning prototype. Engineering is a team effort.

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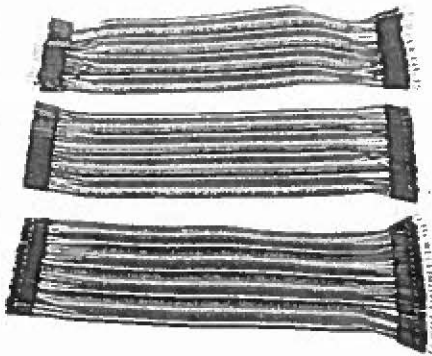
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## Appendix

<b>Bill of materials used (with attached cut sheet)</b>			
<b>Item Name</b>	<b>Description</b>	<b>Place of Purchase</b>	<b>Price per unit</b>
1. Bread board Jumper wires	Provides connection between board and components	Amazon	\$6.39
2. Arduncam LCD Screen	Visual output device for the Arduino	Amazon	\$5.99
3. Hammond 1591 ESBK	Project box to hold all the components together	Amazon	\$7.31
4. IEIK UNO R3 Board ATmega328P with USB Cable for Arduino	Arduino Board	Amazon	\$9.99
5. SunFounder 2 Channel DC 5V Relay Module	Relay board compatible with 5v Arduino system	Amazon	\$6.79
6. Unxcell Push/Pull type solenoid	12-volt solenoid, 10mm stroke 600-gram capacity	Amazon	\$7.36
7. Unxcell Rotary potentiometer	Used as control knob via analog input	Amazon	\$6.22
8. Micro-connectivity IB401	Breadboard with connectors	Amazon	\$6.12
<b>Total</b>			<b>\$56.27</b>

 You purchased this item on January 17, 2017  
[View this order](#)



### Pixnor 3pcs 20cm 40 Pin Male to Male, Male to Female, Female to Female Breadboard Jumper Wires Ribbon Cable

by PIXNOR

★★★★☆ • 10 customer reviews

Price: \$6.39 ~~✓Prime~~

In Stock

Want it tomorrow, Feb. 17? Order within 5 hrs 10 mins and choose **One-Day Shipping** at checkout. Details  
 Sold by DealPe and Fulfilled by Amazon. Gift-wrap available.

- 3 pieces of the 40pin breadboard jumper wires in one set will be sold together
- Each cable length: about 20cm 8-inch
- Include one 40-pin male to female jumper wires, one 40-pin male to male jumper wires, one 40-pin female to female jumper wires
- The male ends meant for insertion into standard 0.1" (2.54mm) female sockets and the female ends are meant for insertion onto standard 0.1" (2.54mm) male headers.
- The cables can be separated in form an assembly containing the number of wires you require for your connection and to support non-standard odd-spaced headers

New (1) from \$6.39 ~~✓Prime~~

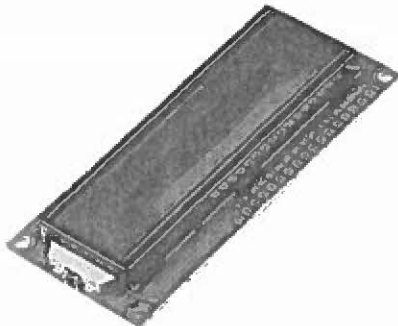
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Sling Television: 7 days FREE

Watch Live TV Programming Any Time and Anywhere. Simple monthly pricing, no long-term contracts or

 You purchased this item on January 17, 2017  
[View this order](#)



by Arducam

### Arducam 1602 16x2 LCD Display Module Based on HD44780 Controller Character White on Blue with Backlight for Arduino

★★★★☆ • 10 customer reviews

Price: \$5.99 ~~✓Prime~~

In Stock

Want it tomorrow, Feb. 17? Order within 3 hrs 39 mins and choose **One-Day Shipping** at checkout. Details  
 Sold by Arducam and Fulfilled by Amazon. Gift-wrap available.

New (1) from \$5.99 ~~✓Prime~~

Specifications for this item

Brand Name	Arducam
Color	Blue
Part Number	C0048
UNSPSC Code	60106401

[See more product details](#)

You purchased this item on January 10, 2017  
 Size: ES - 7.5 x 4.3 x 2.2 inch / 191 x 110 x 57 mm | [View this order](#)



### Hammond 1591ESBK ABS Project Box Black

by Hammond

★★★★☆ 255 customer reviews | 19 answered questions

Price: \$7.31 **FREE Shipping** for Prime members [Details](#)

In Stock

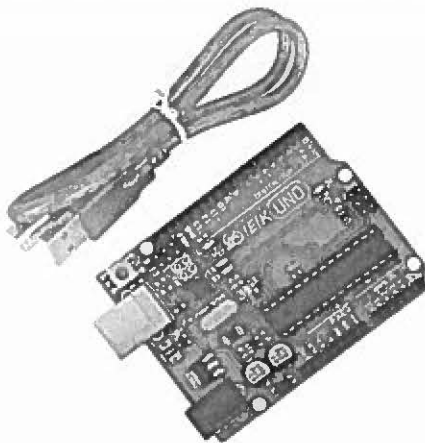
Sold by Gerber Electronics and Fulfilled by Amazon. Gift-wrap available.

Size: ES - 7.5 x 4.3 x 2.2 inch / 191 x 110 x 57 mm

1	AS - 3.9 x 2 x 0.8 inch / 100 x 50 x 21 mm	5
\$6.72 <b>✓Prime</b>	\$5.21 <b>✓Prime</b>	\$37.74
ES - 7.5 x 4.3 x 2.2 inch / 191 x 110 x 57 mm		
\$7.31 <b>✓Prime</b>	\$2.31 <b>4P</b>	

- Price For Each Enclosure Type: Multipurpose Enclosure Material: Plastic Body Color: Black External Height - Imperial: 7.5" External Height - Metric: 191mm External Width - Imperial: 4.3" IP Rating: IP54 RoHS Compliant: Yes
- [See more product details](#)

You purchased this item on December 26, 2016  
[View this order](#)



[Click to open expanded view](#)

### IEIK UNO R3 Board ATmega328P with USB Cable for Arduino - Compatible With Arduino UNO R3 Mega 2560 Nano Robot

by IEIK

★★★★☆ 239 customer reviews | 20 answered questions

Price: \$9.99 **✓Prime**

Buy 10, get 5% off 1 Applicable Promotion(s) \*

In Stock

Want it tomorrow, Feb. 17? Order within 2 hrs 37 mins and choose One-Day Shipping at checkout. [Details](#)  
 Sold by SmilesHopper and Fulfilled by Amazon. Gift-wrap available.

- 1 x UNO R3 Rev3 Development Board
- 1 x USB Cable

New (3) from \$9.99 **✓Prime**

[Report incorrect product information](#)

VIA STAR

**Buy Vastar 454G Activity Wire Solder**

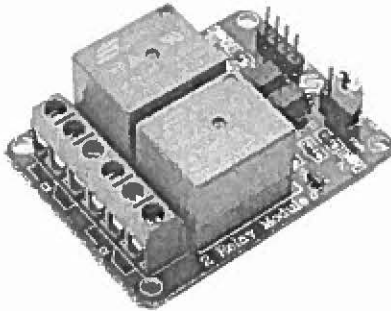
**✓Prime**



Vastar 454G Activity Wire Solder  
 ★★★★★ 10  
 \$23.99 \$23.99 **✓Prime**

[Add Feedback](#)

 You purchased this item on December 26, 2018  
Size: 2 Channel | [View this order](#)



Roll over image to zoom in

### SunFounder 2 Channel DC 5V Relay Module with Optocoupler Low Level Trigger Expansion Board for Arduino UNO R3 MEGA 2560 1280 DSP ARM PIC AVR STM32 Raspberry Pi

by SunFounder  
★★★★☆ • 103 customer reviews | 31 answered questions

Price: \$6.79 ✓Prime

In Stock.

Want it tomorrow, Feb. 17? Order within 5 hrs 7 mins and choose **One Day Shipping** at checkout. Details  
Sold by: SunFounderUS and fulfilled by Amazon. Gift-wrap available.

Size: 2 Channel

2 Channel	4 Channel	8 Channel
\$6.79 ✓Prime	\$4.99 ✓Prime	\$11.99 ✓Prime

- 5V 2-Channel Relay interface board, and each one needs 15-20mA Driver Current
- Equipped with high-current relay: AC250V 10A / DC30V 10A
- Standard interface that can be controlled directly by microcontroller (Arduino, 8051, AVR, PIC, DSP, ARM, ARM, MSP430, TTL logic)
- Indication LEDs for Relay output status
- Link to download the document: [http://www.sunfounder.com/sk/index.php?title=2\\_Channel\\_5V\\_Relay\\_Module](http://www.sunfounder.com/sk/index.php?title=2_Channel_5V_Relay_Module)
- See more product details

Used & new (1) from \$6.79 ✓Prime

☐ Report incorrect product information

 You purchased this item on December 10, 2018  
[View this order](#)



by Uxcell

### Uxcell Push Pull Open Frame Solenoid Electromagnet, 10 mm Stroke, 600 g, DC 12V 1A

★★★★☆ • 26 customer reviews | 10 answered questions

Price: \$7.36 ✓Prime

**Note:** Available at a lower price from other sellers, potentially without free Prime shipping.

Only 8 left in stock (more on the way)

Want it tomorrow, Feb. 17? Order within 3 hrs 36 mins and choose **One Day Shipping** at checkout. Details  
Ships from and sold by Amazon.com. Gift-wrap available.

New (5) from \$6.01 & FREE shipping

#### Specifications for this item

Brand Name	Uxcell	Part Number	313126200us0516
EAN	0700724661418	System of Measurement	Metric
Item Weight	0.32 ounces	UNSPSC Code	39121552
Material Type	Metal Electronic Parts	UPC	700724661418
Number of Items	1		

 You purchased this item on December 10, 2016  
[View this order](#)



Roll over image to zoom in

by **uxcell**

### Uxcell Rotary Carbon Potentiometer with Diameter with Knob, RV24YN 20S B103 10K Ohm

☆☆☆☆☆ • 3 customer reviews

Price: \$6.22 **~Prime**

**In Stock**

Want it tomorrow, Feb. 17? Order within 4 hrs 6 mins and choose **One-Day Shipping** at checkout [Details](#)

Sold by **uxcell** and Fulfilled by Amazon. Gift wrap available

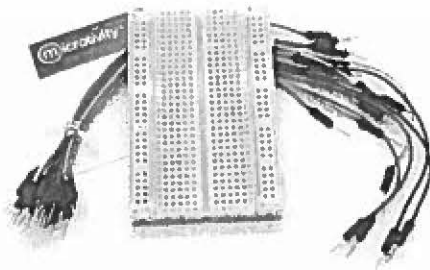
**New (1)** from \$5.63 & FREE shipping

#### Specifications for this item

Brand Name	uxcell
EAN	0711331502894
Number of Items	1
Part Number	a15050500ux0776
UNSPSC Code	41113633
UPC	711331502894

SPC00015028941851863

 You purchased this item on December 10, 2016  
[View this order](#)



Roll over image to zoom in

### microtivity IB401 400-point Experiment Breadboard w/ Jumper Wires

by **microtivity**

☆☆☆☆☆ • 171 customer reviews | 8 answered questions

Price: \$6.12 **~Prime**

**Note:** Available at a lower price from other sellers, potentially without free Prime shipping.

**In Stock**

Sold by **BasicNote** and Fulfilled by Amazon

- 400-Tie-point breadboard (white) with peelable adhesive tape at the back
- Comes with 20 male-male jumper wires of various colors
- Works great with Arduino
- Also great for electronic and electrical experiments
- Dimensions: 64 x 55mm (3.31" x 2.15")

**New (7)** from \$4.29 & FREE shipping

☐ Report incorrect product information

CANAKIT

### Canakit Raspberry Pi Starter Kit

[Shop here](#)



Canakit Raspberry Pi 3 Complete Starter Kit - 32 GB Edition

☆☆☆☆☆ 1,363

\$74.95 **~Prime**

[Add feedback](#)

## Ardunio Technical Specifications

### Technical specs

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

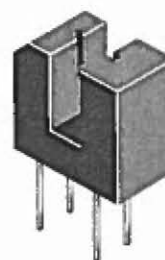
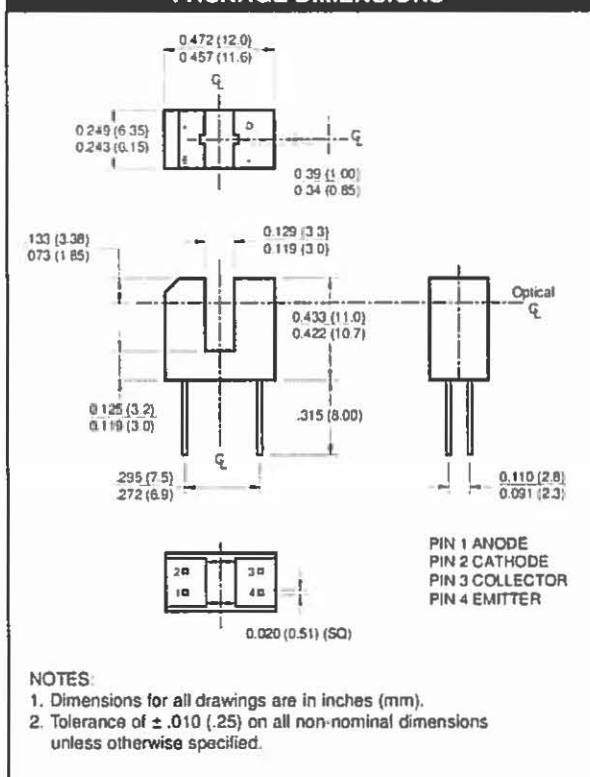
# Phototransistor Optical Interrupter Switch Technical Information

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SEMICONDUCTOR®

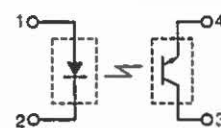
## PHOTOTRANSISTOR OPTICAL INTERRUPTER SWITCH

**CNY36**

### PACKAGE DIMENSIONS



### SCHEMATIC



### DESCRIPTION

The CNY36 is a gallium arsenide infrared emitting diode coupled with a silicon phototransistor in a plastic housing. The gap in the housing provides a means of interrupting the signal with tape, cards, shaft encoders, or other opaque material, switching the output from an "ON" to an "OFF" state.

### FEATURES

- Opaque housing
- Low cost
- .035" apertures
- European "Pro Electron" registered



# PHOTOTRANSISTOR OPTICAL INTERRUPTER SWITCH

## CNY36

### ABSOLUTE MAXIMUM RATINGS ( $T_A = 25^\circ\text{C}$ unless otherwise specified)

Parameter	Symbol	Rating	Unit
Operating Temperature	$T_{OPR}$	-55 to +85	$^\circ\text{C}$
Storage Temperature	$T_{STG}$	-55 to +85	$^\circ\text{C}$
Soldering Temperature (Iron)(3,4 and 5)	$T_{SOL I}$	240 for 5 sec	$^\circ\text{C}$
Soldering Temperature (Flow)(3 and 4)	$T_{SOL F}$	260 for 10 sec	$^\circ\text{C}$
<b>INPUT (EMITTER)</b>			
Continuous Forward Current	$I_F$	60	mA
Reverse Voltage	$V_R$	3	V
Power Dissipation (1)	$P_D$	100	mW
<b>OUTPUT (SENSOR)</b>			
Collector to Emitter Voltage	$V_{CEO}$	30	V
Emitter to Collector Voltage	$V_{ECO}$	5.0	V
Power Dissipation ( $T_C = 25^\circ\text{C}$ )(1)	$P_D$	150	mW

### ELECTRICAL / OPTICAL CHARACTERISTICS ( $T_A = 25^\circ\text{C}$ )(All measurements made under pulse condition)

PARAMETER	TEST CONDITIONS	SYMBOL	DEVICES	MIN	TYP	MAX	UNITS
<b>INPUT (EMITTER)</b>							
Forward Voltage	$I_F = 10 \text{ mA}$	$V_F$	All	—	—	1.7	V
Reverse Leakage Current	$V_R = 2 \text{ V}$	$I_R$	All	—	—	1.0	$\mu\text{A}$
<b>OUTPUT (SENSOR)</b>							
Emitter to Collector Breakdown	$I_E = 100 \mu\text{A}$ , $E_e = 0$	$BV_{ECO}$	All	5.0	—	—	V
Collector to Emitter Breakdown	$I_C = 10 \text{ mA}$ , $E_e = 0$	$BV_{CEO}$	All	30	—	—	V
Collector to Emitter Leakage	$V_{CE} = 10 \text{ V}$ , $E_e = 0$	$I_{CE0}$	All	—	—	100	nA
<b>COUPLED</b>							
On-State Collector Current	$I_F = 20 \text{ mA}$ , $V_{CE} = 10 \text{ V}$	$I_{C(ON)}$	All	2.0	—	—	mA
Saturation Voltage	$I_F = 20 \text{ mA}$ , $I_C = 25 \mu\text{A}$	$V_{CE(SAT)}$	All	—	—	0.40	V
Turn-On Time	$I_F = 30 \text{ mA}$ , $V_{CE} = 5 \text{ V}$ , $R_L = 2.5 \text{ k}\Omega$	$t_{ON}$	All	—	5	—	$\mu\text{s}$
Turn-Off Time	$I_F = 30 \text{ mA}$ , $V_{CE} = 5 \text{ V}$ , $R_L = 2.5 \text{ k}\Omega$	$t_{OFF}$	All	—	5	—	$\mu\text{s}$

#### NOTE:

- Derate power dissipation linearly 1.67 mW/ $^\circ\text{C}$  above  $25^\circ\text{C}$ .
- Derate power dissipation linearly 2.50 mW/ $^\circ\text{C}$  above  $25^\circ\text{C}$ .
- RMA flux is recommended.
- Methanol or isopropyl alcohols are recommended as cleaning agents.
- Soldering iron tip 1/16" (1.6mm) minimum from housing.



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# PHOTOTRANSISTOR OPTICAL INTERRUPTER SWITCH

**CNY36**

Figure 1. Output Current vs. Input Current

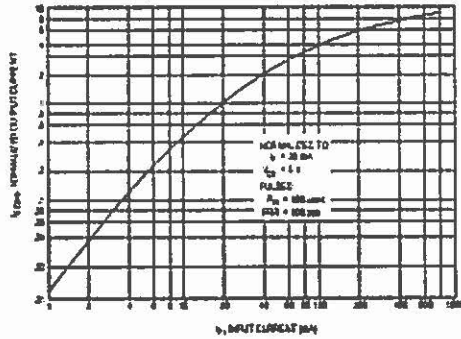


Figure 2. Output Current vs. Temperature

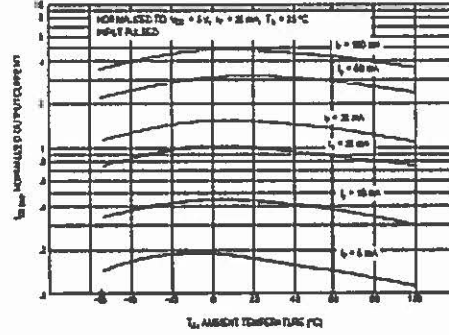


Figure 3. Voltage vs. Temperature

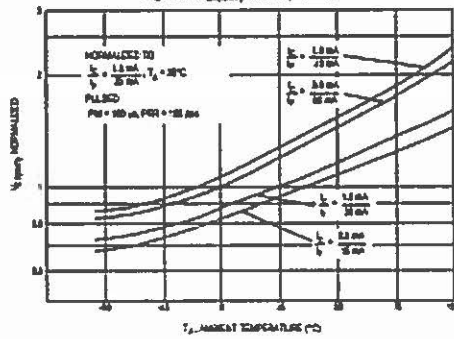


Figure 4. Leakage Current vs. Temperature

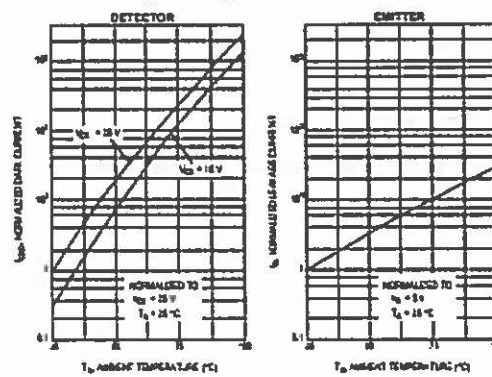


Figure 5. Switching Speed vs.  $R_L$

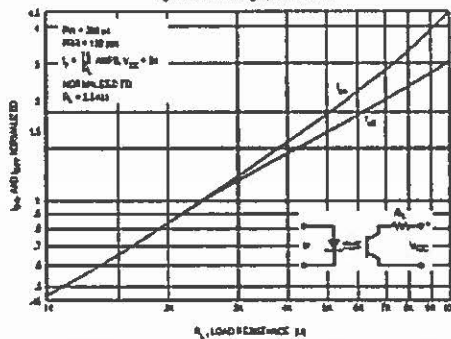
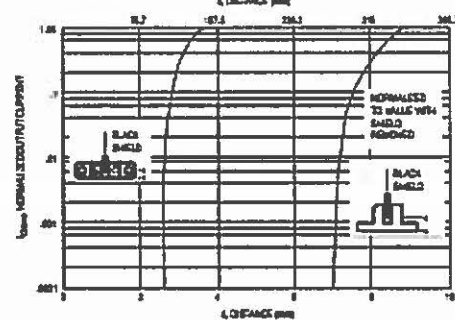


Figure 6. Output Current vs. Distance





## PHOTOTRANSISTOR OPTICAL INTERRUPTER SWITCH

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**CNY36**

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

